XYIDS000216

PCT

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G01N 15/14 A1

(11) International Publication Number: WO 89/ 04472

(43) International Publication Date: 18 May 1989 (18.05.89)

(21) International Application Number: PCT/GB88/00974

(22) International Filing Date: 10 November 1988 (10.11.88)

(31) Priority Application Number: 8726305

(32) Priority Date: 10 November 1987 (10.11.87)

(33) Priority Country: GB

(71) Applicant *(for all designated States except US)*: THE SECRETARY OF STATE FOR DEFENCE IN HER BRITANNIC MAJESTY'S GOVERNMENT OF THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND [GB/GB]; Whitehall, London SW1A 2HB (GB).

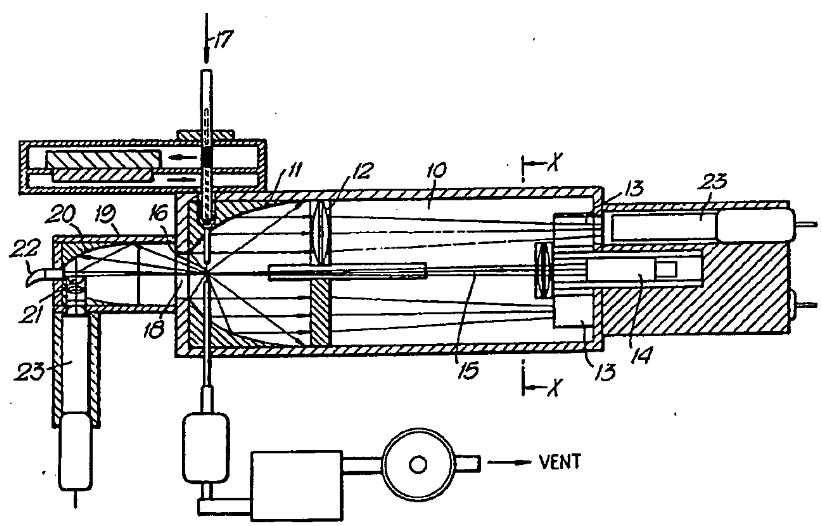
(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : LUDLOW, Ian, Keith [GB/GB]; Parkway Close, Welwyn Garden City, Hertfordshire (GB). KAYE, Paul, Henry [GB/GB]; 1 Coopers Close, Kimpton, Hertfordshire (GB).

(74) Agent: BECKHAM, Robert, William; Ministry of Defence, Procurement Executive, Patents 1A(4), Room 2014, Empress State Building, Lillie Road, London SW6 1TR (GB).

(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), DK, FI, FR (European patent), GB, GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), NO, SE (European patent), US.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: PORTABLE PARTICLE ANALYSERS



(57) Abstract

A portable particle analyser is compact and can determine the size, geometry and number of particles in a sample of fluid. A laser beam (15) intercepts the flow of fluid (17) at the first focal point of a parabolic mirror (11). Light is scattered and collected by radiation collectors (13) and low angle scattered radiation is detected in a second chamber (19) by reflection by an ellipsoid mirror (20) towards a radiation collector (21). Photomultiplier units (23) convert the radiation collected into electrical signals for analysis.

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PORTABLE PARTICLE ANALYSERS

This invention relates to apparatus for the analysis of fluid-borne particles. For example, in the study of aerosols, aerosol dispersion and airborne particulate pollution control, there is a requirement for the rapid determination of particle size distribution especially in the diameter range 1 to 10 microns, together with some knowledge of the geometry and symmetry of individual particles. The latter information could, for example, enable particles with spherical symmetry to be identified and thus allow the counting/monitoring of liquid droplets in an environment including other solid, non-spherical particles. In the context of the present specification, the term particles is intended to apply both to solid bodies and to drops of liquid.

It is desirable for such apparatus to be able to count individual particles in a sample at rates of, typically, 20,000 particles per second, to be able to distinguish between spherical and non-spherical particles in the sample and to count each type. Another desirable feature is to categorise spherical particles having diameters of a few microns into a number of size bands and also in this connection to classify particle coincidences as 'non-spherical' and hence to ignore them in the compilation of size spectra based on the assumption the particle is spherical.

The normal techniques for the examination of particles, as used in several instruments available commercially, employ the detection and analysis of electromagnetic radiation scattered by the particles. All such instruments use a mechanical mechanism to drive the sample air through a "sensing volume" where the carried particles are illuminated by the incident electromagnetic radiation. The radiation scattered by the particles is received by one or more detectors which convert the energy to electrical signals from which information may be extracted by appropriate electrical circuits.

Particle analysers are known, for example, as described in UK Patent Application numbers 8619050, 2041516A, 2044951A and US Patent No 3946239. These all describe analysers which comprise a concave reflector in a scatter chamber, and a flow of sample fluid intercepted by a beam of radiation. The light scattered from individual particles in the fluid is directed by the reflector to radiation collectors and

subsequently analysed. All of these, however, suffer from being cumbersome and fragile and consequently not readily portable. Moreover, light scattered at low angles from the particles in the sample is not detected by any of the above prior art systems.

There is therefore a need for a particle analyser which is portable and compact and determines the size, geometry and number of particles in a sample fluid, and is additionally capable of detecting and analysing light scattered at low angles from the individual particles in the sample.

According to one aspect of the present invention a particle analyser includes a first scatter chamber, means for providing a sample of fluid in the form of a laminar flow through the first scatter chamber, a beam of radiation, adapted to intercept the sample at right angles to a direction of flow of the sample at a focal point of a first concave reflector, the first concave reflector being used to direct the radiation scattered by individual particles in the sample towards at least one radiation collector, means for converting the radiation collected into electrical signals for processing and analysis, and means for dumping the non-scattered radiation wherein an aperture in the first concave reflector leads to a second scatter chamber.

The beam of radiation may be provided by a laser which may be mounted in any one of a number of ways so that the beam intercepts the sample flow at right angles. For example, it may be mounted aligned with the principal axis of the first concave reflector; such an arrangement would make the apparatus more rugged and compact.

The first concave reflector may be a parabolic mirror, or, alternatively may be an ellipsoid mirror, which would reflect the scattered light to a single point of detection.

The advantage of having a second chamber mounted coaxially with the first chamber is so that light scattered at low angles from the individual particles in the sample can be detected and analysed also. This information is particularly useful in determining the size of particles. The second chamber may or may not include a second concave reflector. If no second concave reflector is used the second chamber may include radiation collectors mounted around the unscattered beam, for example in concentric rings. If a second concave reflector is used it is preferably an ellipsoid mirror, has a radiation collector

located at a near focal point and a far focal point at the point of interception of the beam and sample. Thus, light scattered at low angles is reflected by the ellipsoid mirror to the near focal point and collected by the radiation collector there.

Radiation collectors of any suitable type may be used in the present invention and may include photomultiplier units, optical fibre leading to such units or lenses directing the radiation to a photomultiplier unit or optical fibre.

According to a second aspect of the present invention a method of particle analysis includes the steps of:

passing a sample of fluid in the form of a laminar flow through a first scatter chamber;

passing a beam of radiation through the first scatter chamber so as to intercept the sample at right angles to a direction of flow at a focal point of a first concave reflector, the first concave reflector being used to direct the radiation towards at least one radiation collector;

collecting scattered radiation with at least one radiation collector located in a second chamber leading from an aperture in the first concave reflector;

converting the radiation collected into electrical signals, processing and analysing the electrical signals; and dumping the non-scattered radiation.

The sample may be an aerosol.

A number of embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Fig 1 is a side view in section of a preferred embodiment of the invention;

Fig 1a is a view along the line in Fig 1;

Fig 2 is a side view in section of another embodiment of the invention; and

Fig 3 is a side view in section of a further embodiment of the invention.

As shown in Fig 1 a first scattering chamber 10 includes a first concave reflector in the form of a parabolic mirror 11, lenses 12, and radiation collectors 13. A laser 14 is mounted aligned with the

principal axis of the parabolic mirror 11 and directs a beam 15 of radiation towards the focal point 16 of the parabolic mirror 11 where it intercepts with the sample fluid 17 in the form of a laminar flow. An aperture 18 leads to a second chamber 19 which includes a second concave reflector in the form of an ellipsoid reflector 20 and a radiation collector 21 located at the near focal point of the ellipsoid reflector 20 and the ellipsoid reflector is positioned so that its far focal point is situated at the focal point 16 of the first parabolic reflector 11. A beam dump 22, typically a Rayleigh horn is located at an aperture in the ellipsoid mirror 20 to collect the non-scattered radiation. Radiation collectors 13 and 21 are connected to photo-multiplier tubes 23. Fig 1a shows a possible arrangement of radiation collectors 13 around the laser 14. Although only three collectors are shown here, any number of detectors may be located radially around the laser 14.

Fig 2 shows an alternative embodiment of the invention where the laser 14 is mounted at an angle of 90° to the principal axis of the first concave reflector which, in this embodiment, is an ellipsoid reflector 40. A 45° mirror 41 is mounted on the principal axis of the reflector 40 and is used to direct the laser beam 15 along the principal axis and towards the aperture 18 in the ellipsoid reflector 40. Indeed, the laser 14 may be mounted just about anywhere about the first scatter chamber 10 with an appropriately angled mirror 41 on the axis. The sample of fluid in laminar flow 17 is directed perpendicular to the paper to intersect the beam 15 at the focal point 16 of the ellipsoid reflector 40. A collection lens 12 directs scattered light towards radiation collector 13 which is connected via optical fibres 42 to photomultiplier tubes 43. The second chamber 19 is non-reflecting and includes a plurality of optical fibres 43 arranged around the beam 15 and connected to photomultiplier tubes 23. The optical fibres 43 may be arranged in concentric rings around the beam 15.

A further embodiment of the invention is shown in Fig 3. In this embodiment both the first reflector 50 and the second reflector 51 are both ellipsoid mirrors. Once again, the laser 14 is at an angle of 90° to the principal axes of the reflectors, so that mirror 41 directs the beam 15 along the principal axis. The sample 17 is directed at

right angles to the laser beam 15 and intercepts it at the near focal point 16 of the first ellipsoid reflector 50. The second ellipsoid reflector 51 is positioned so that its far focal point coincides with point 16. Photomultiplier tubes 23 are located at the far focal point of the first ellipsoid reflector 11 and at the near focal point of the second ellipsoid reflector 20 to collect the scattered radiation. The beam dump 22 is located within the second scatter chamber 19 to dump the non-scattered radiation.

The radiation collector 23 in Fig 3 is positioned to face the aperture 18 in the first chamber 10 as opposed to being placed at 90° to this direction as shown in Fig 1. The latter arrangement would collect relatively more radiation of low angle deflection, but less overall since only deflections in the direction of the face of the collector will be recorded.

In use, the sample of fluid 17 is supplied in laminar flow by means of a sheath of constant velocity air being supplied around the sample, as shown in Figs 1 and 3. This is so that the outer parts of the sample flow have the same velocity as the inner parts. The outer parts of the sample would otherwise flow more slowly due to friction with stationary air next to the sample flow. Additionally, a coaxial tube supplying the sheath of air is designed to dynamically focus particles in the sample to provide a laminar flow of particles. The laser beam 15 intercepts at right angles the flow of fluid 17 and light is scattered from the individual particles contained in the fluid. The scattered radiation reflects off the walls of the first concave reflector in the first scatter chamber 10. If first concave reflector is a parabolic mirror 11 (Fig 1) the radiation is reflected parallel to its principal axis or if it is an ellipsoid mirror 40 and 50 (in Figs 2 and 3), the radiation is directed to the far focal point of the mirror. This deflected radiation is then directed towards photomultiplier tubes 23 either directly, as in Fig 3, or by using lenses 12 as in Fig 1 to direct the radiation towards the photomultiplier units 23, or as shown in Fig 2 using lenses 12 and optical fibres 42 to direct the radiation towards photomultiplier units 23.

Radiation scattered at low angles by the particles is collected in the second chamber 19, which may include an ellipsoid mirror 20 and 51 in Figs 1 and 3 and radiation collectors which may be a photo-

multiplier tube 23 as in Fig 3 or a lens 21 in Fig 1 leading to such a tube 23. Alternatively the second chamber may not include a reflector in which case the scattered radiation is collected by optical fibres 43 surrounding the non-scattered beam 15. Any non-scattered radiation is dumped by a beam dump 22, typically a Rayleigh horn.

All the radiation collected is then converted into electrical signals, processed and analysed, and the information may be extracted by appropriate electronic circuits.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made without departing from the scope of the invention as defined in the appended claims.

CLAIMS

What is claimed is:-

1. A particle analyser including a first scatter chamber, means for providing a sample of fluid in the form of a laminar flow through the first scatter chamber, a beam of radiation, adapted to intercept the sample at right angles to a direction of flow at a focal point of a first concave reflector, the first concave reflector being used to direct the radiation scattered by individual particles in the sample towards at least one radiation collector, means for converting the radiation collected into electrical signals for processing and analysis, and means for dumping the non-scattered radiation wherein an aperture in the first concave reflector leads to a second scatter chamber.

2. A particle analyser as claimed in Claim 1 wherein the beam of radiation is supplied by a laser.

3. A particle analyser as claimed in Claim 2 wherein the laser is mounted on and aligned with the principle axis of the first concave reflector.

4. A particle analyser as claimed in Claim 1 or Claim 2 wherein a small reflector is mounted on the principal axis of the concave reflector to reflect the beam from a laser mounted at an angle to the principle axis.

5. A particle analyser as claimed in Claim 4 wherein the angle is 90 degrees.

6. A particle analyser as claimed in Claim 2 wherein the laser is mounted on and aligned with an axis which is at right angles both to the principle axis of the reflector and to the direction of flow of the sample.

7. A particle analyser as claimed in any previous Claim wherein the first concave reflector is a parabolic reflector.

8. A particle analyser as claimed in Claims 1 to 6 wherein the first concave reflector is an ellipsoid with the point of interception at the proximal focal point, and a radiation collector at or near the distal focal point.

9. A particle analyser as claimed in any previous Claim wherein the second chamber comprises a second concave reflector with a radiation collector located at its near focal point and positioned so that its far focal point is at the point of interception of the beam of radiation and the sample.

10. A particle analyser as claimed in Claim 9 wherein the second concave reflector is a parabolic reflector.

11. A particle analyser as claimed in Claim 9 wherein the second concave reflector is an ellipsoidal reflector.

12. A particle analyser as claimed in Claim 1 wherein the second chamber includes radiation collectors mounted around the unscattered beam.

13. A particle analyser as claimed in any previous Claim wherein the or each radiation collector is a photo-multiplier unit.

14. A particle analyser as claimed in any one of Claims 1 to 12 wherein the or each radiation collector is an optical fibre leading to a photo-multiplier unit.

15. A particle analyser as claimed in any one of Claims 1 to 12 wherein the or each radiation collector is a lens directing the radiation up to a photo-multiplier unit or an optical fibre.

16. A method of particle analysis including the steps of: passing a sample of fluid in the form of a laminar flow through a first scatter chamber; passing a beam of radiation through the first scatter chamber so as to intercept the sample at right angles to a direction of flow at a focal point of a first concave reflector, the first concave reflector being used to direct the radiation towards at least one radiation collector; collecting scattered radiation with at least one radiation collector located in a second chamber leading from an aperture in the first concave reflector; converting the radiation collected into electrical signals; processing and analysing the electrical signals; and dumping the non-scattered radiation.

17. A method of particle analysis as claimed in Claim 16 wherein the sample is an aerosol.

18. A particle analyser substantially as herein described with reference to the accompanying diagrammatic drawings.

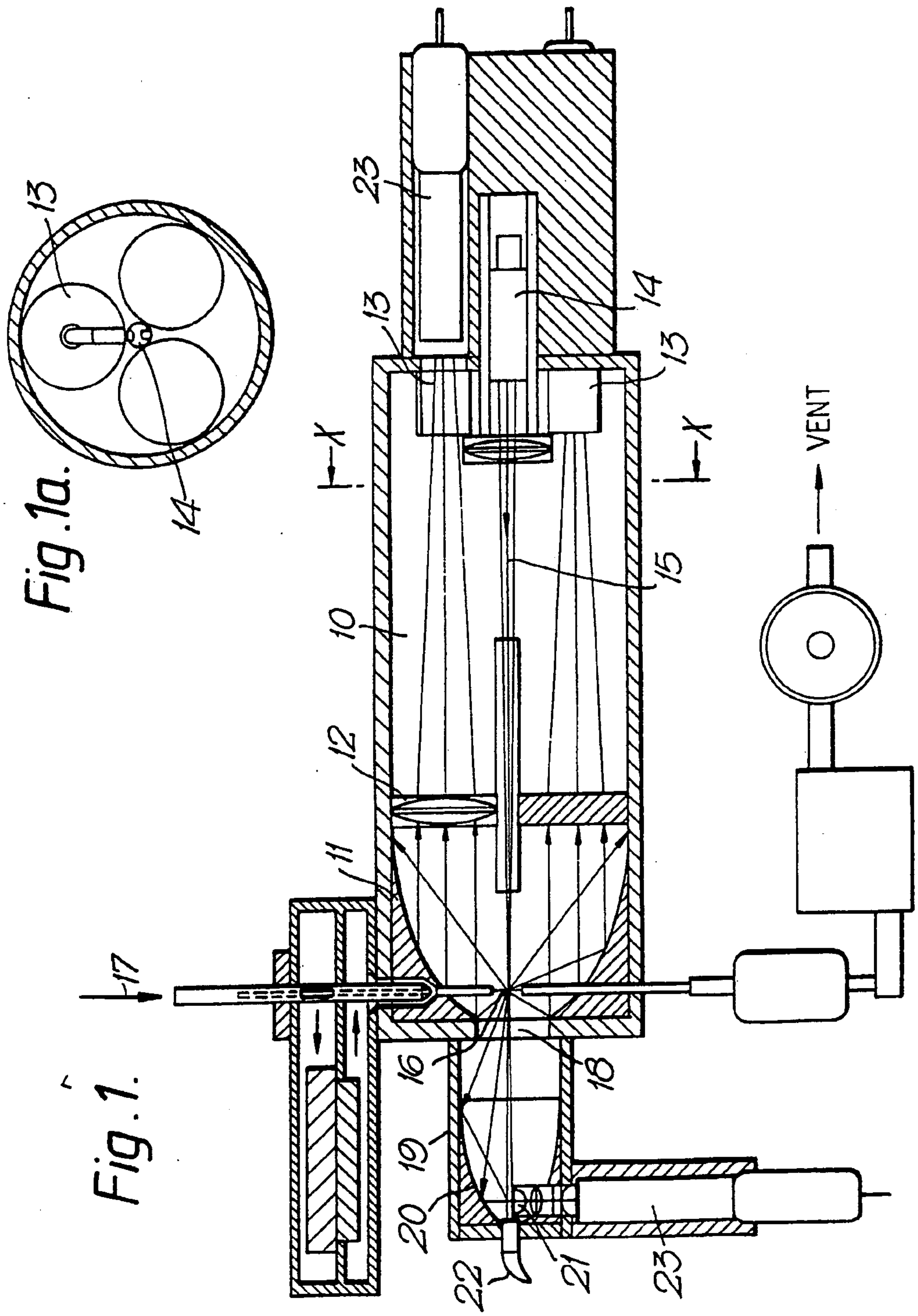


Fig.1a.

Fig.1.

Fig. 2.

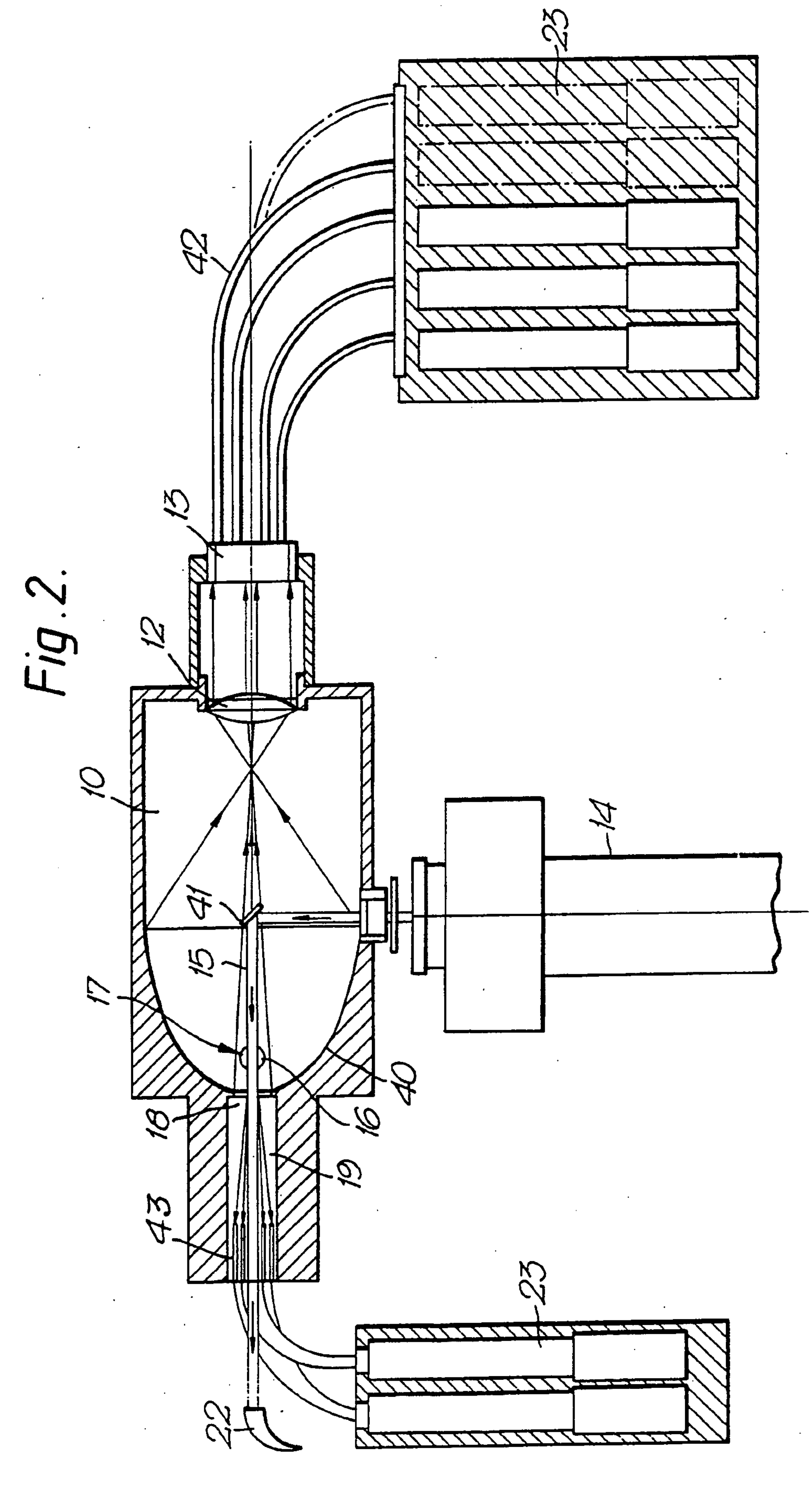
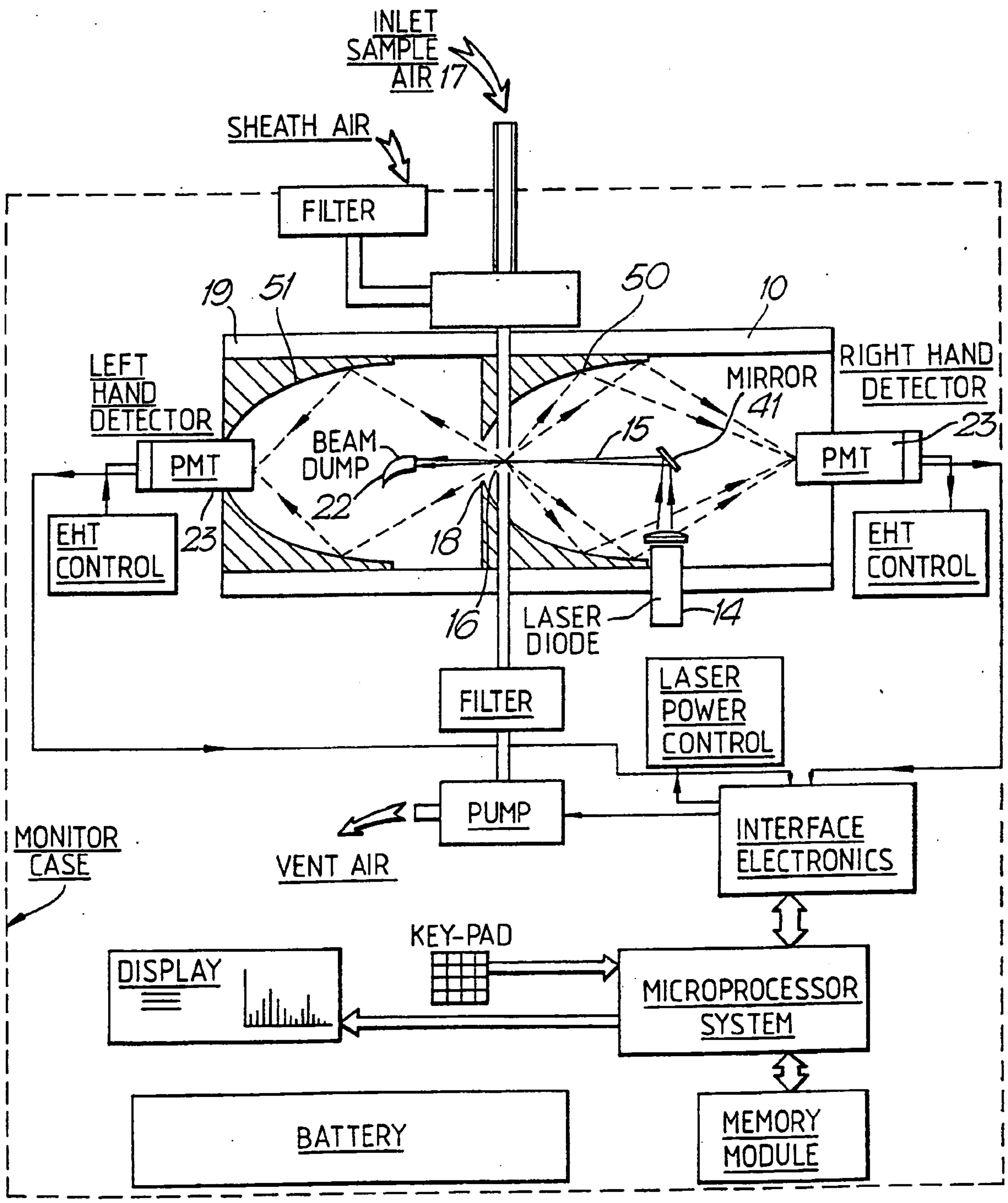


Fig.3.


INLET SAMPLE AIR 17
SHEATH AIR
FILTER
19
51
50
10
LEFT HAND DETECTOR
RIGHT HAND DETECTOR
MIRROR 41
BEAM DUMP 22
15
PMT
23
EHT CONTROL
18
16
LASER DIODE
14
FILTER
LASER POWER CONTROL
PUMP
VENT AIR
MONITOR CASE
INTERFACE ELECTRONICS
KEY-PAD
DISPLAY
MICROPROCESSOR SYSTEM
BATTERY
MEMORY MODULE

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 8800974

SA 25162

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00974

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 01 N 15/14

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 01 N 15/14; G 01 N 15/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	GB, A, 2041516 (COULTER ELCTRONICS) 10 September 1980, see page 6, line 130; page 7, lines 1-88; figure 4 (cited in the application)	1-6,8,12, 14-16
X	US, A, 4200802 (G. SALZMAN et al.) 29 April 1980, see column 2, lines 11-68; figure 1 (cited in the application)	1,7
X	FR, A, 2535051 (UNIVERSITE SAINT ETIENNE) 27 April 1984, see page 6, lines 19-37; page 7; page 8, lines 1-27	1-5,14
A	Aerosol Measurement, editor D. Lundgren published 1979 Gainerville, (US) R.W. Storey: "Aerosol field measurements using light-scattering photometers", pages 241-259, see pages 241-244: "Instruments"	1,8,13,17

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
8th February 1989	-9. 03. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)